DOI: 10.19180/2177-4560.v8n214-04

Water reuse and its importance for firefighting training of offshore workers

A água de reúso e a sua importância para treinamento dos trabalhadores offshore no combate a incêndio

Severino Joaquim Correia Neto*
Fernando Benedicto Mainier**
Marcos Antonio Cruz Moreira***

Abstract

Consumption of freshwater has grown dramatically worldwide due to the increase of population in urban areas, irrigation of agri-business and the use of water in industrial processes, resulting in sanitary and industrial effluents. This brings urgent need to save, reduce, recycle, reuse, as well as develop processes that do not go against society, or are based on precautionary principles, considering the possibility of contamination of a chemical and microbiological elements present in effluents. This study evaluated a critical process for reuse in general and, more specifically, in Fire Fighting Training Centers, where training consumes considered volume of water as the main extinguishing agent. The simple and creative technologies developed for the study prove the success of water reuse to fight waste.

Key words: Reuse. Contamination. Precautionary principle. Fire fighting.

Resumo

O consumo de água doce no mundo tem crescido vertiginosamente em função do aumento da população nas áreas urbanas, da irrigação no agronegócio e do uso de água nos processamentos industriais, gerando, consequentemente, efluentes sanitários e industriais. Isso remete à necessidade precípua de poupar, reduzir, reciclar e desenvolver processos de reúso que não venham na contramão da sociedade, ou seja, estejam baseados nos princípios da precaução, considerando a possibilidade de ocorrências de contaminações de ordem química e microbiológica presentes nos efluentes. O presente trabalho avaliou numa visão crítica os processos de reúso de uma maneira geral e, mais precisamente, em Centros de Treinamento de Combate a Incêndio onde o treinamento consome considerado volume de água como agente extintor. As tecnologias simples e criativas desenvolvidas comprovam o sucesso do reúso da água no combate ao desperdício.

Palavras-chave: Reúso. Contaminações. Princípio da precaução. Treinamento. Incêndio.

* Master of Science in Management Information Systems from Universidade Federal Fluminense (UFF). Professor at the Federal Institute of Education Science and Technology Fluminense (IFFluminense) *campus* Macaé, Campos dos Goytacazes/RJ - Brazil. E- mail: scorreia@iff.edu.br

** Doctor of Education from the Federal University of Rio de Janeiro (UFRJ). Professor at the Fluminense Federal University (UFF) - Niterói/RJ - Brazil E-mail: mainier@vm.uff.br

*** Doctor of Electrical Engineering from the Federal University of Rio de Janeiro (UFRJ). Professor at the Federal Institute of Education, Science and Technology Fluminense (IFFluminense), *campus* Macaé - Macaé / RJ - Brazil. E- mail: macruz@iff.edu.br

1 Introduction

The opinion of renowned environmental experts is that water will become, along the twenty-first century, an important and disputed natural resource from an economic, social, environmental and political view, such as coal and oil were for global economy over the past 150 years (MACHADO, 2004).

Earth's hydrological cycle is represented by the interdependence and continuous movement of water in solid, liquid and gas phases. Clearly, the liquid phase is the most interesting one, as it is fundamental to the needs of human beings, as well as to all other organisms, be it animals or plants.

According to Tundisi (2005), the hydrological cycle components are:

- Precipitation: water added to the Earth's surface from the atmosphere, occurring as liquid (rain) or solid (snow or ice);
- Evaporation: the transformation of water from liquid into gas (water vapor). Most of the evaporation occurs from the oceans, as well as from lakes, rivers and dams:
  - Transpiration: the process of loss of water vapor by plants, which enters into the atmosphere;
  - Infiltration: the process by which water is absorbed by the soil;
  - Percolation: the process by which water enters the soil and rock formations as far as the water table;
  - Drainage: water displacement movement on the surfaces during precipitation.

Until the late 80s, the hydrologic cycle on the planet was believed to be closed, meaning that the total amount of water would always remain the same since the beginning of the Earth. No water would enter planet Earth from outer space, and no water would go out of it. Recent discoveries, however, suggest that "snowballs" of 20 to 40 tons, called "small comets" by scientists, coming from other regions of the solar system, may reach the Earth's atmosphere. "Snowball" rains vaporize when they approach the atmosphere and may have added three trillion tons (volume = 3x106 km^3) of water in 10,000 years. The speed of the hydrologic cycle varies from one geological era to another, as well as the total sum of marine and freshwaters; in other words, water on the planet is related to life cycles (TUNDISI, 2005).

Currently, one third of the world´s population faces water scarcity due to failures in the management of sources and the increasing use of water, mainly for agriculture. Water shortage is increasing faster than expected, with agriculture accounting for 80% of the world consumption (UN, 2006).

Global use of water has increased six times in the last hundred years, and will probably double by 2050, mainly due to the culture of irrigation. Of the existing species on Earth, humans are the ones that use more freshwater, reaching about 54% of the total available at the present days. If this current trend goes on, mankind will absorb 90% of the available freshwater in the next 25 years, leaving only 10% to the other inhabitants of our planet. (PLANET ORGANIC, 2006)

According to Liu (2011), new waste water treatment techniques should be developed to guarantee minimum quality in the use of reclaimed water for food production. According to Machado (2004), water will become, in fact, a strategic development resource for most countries and for the quality of life, especially for Brazil.

In Braga et al. (2007), water resources can be used in several ways, serving various industrial, agricultural and social activities developed by man. The growing demands for freshwater is due to the population increase, as well as to the expansion of irrigated agricultural areas and the use of water in various industrial segments. On the other hand, to this scenario, misuse, waste and contamination of all kinds should also be added which, consequently, end up generating reduction and gradual deterioration of water quality. According to Mainier (1999b), it is common to see cities where the quality of water is doubtful, as there is neither drinking water nor sewage treatments. Likewise, there is no piped water distribution, which results in the proliferation of black ditches everywhere. Without proper guidance, local populations must look for water in shallow wells, streams and weirs that, somehow, end up receiving pollution charges.

In arid regions, where water is a limiting factor for the development of irrigated agriculture, industrial sectors and urban social activities, reclaimed water becomes an attractive prospect in terms of technical, economic and public policy for sustainability.

Water reuse is already being widely used in industry, especially in cooling towers, boilers, civil construction, green areas irrigation, and in some industrial processes in which the use of lower quality water does not cause major problems. Thus, water reuse for non-potable (drinking) purposes should be considered as the first option for reuse (MIERZA; HESPANHOL, 2002).

An alternative that can be considered for integrating reuse activities is the use of production process wastewater, which requires higher quality water in another process that may use lower quality water. This alternative is environmentally correct; however, it continues incorporating impurities to water receiving bodies.

Melin et al. (2005) developed a technology for wastewater treatment and its reuse as industrial process water through membrane bioreactors (MBRs).

The most interesting alternative is the reuse of water in a closed loop, in other words, by using an adequate treatment process, obtaining water with its initial quality after using it in any activity that results in the incorporation of impurities.

Gomez-Lopez et al. (2009) consider the environmental and social impacts resulting from the wastewater treatment complex, and that different treatments are needed, depending on their future application.

From an environmental perspective, water reuse is a correct choice, since it contributes to reduced uptake and consequent outflow reduction in the discharge of effluents. Nevertheless, in order to be used, aspects regarding public health should be taken into account. In some countries, there are standards that make the reuse of water for non-potable use a common practice.

Nowadays, in regard to water scarcity areas, 26 countries are home to 262 million people. The aggravating factor is that population is growing faster where water shortage is more acute. In the Middle East, 9 out of 14 countries live in scarcity conditions, six of which will probably double their population within 25 years. In this region, the excessive withdrawal of water from underground aquifers causes ocean salinity intrusion, which contaminates groundwater.

2 Methodology

This work was based on a review of the literature - books, journal articles, national and international legislation standards, sources that include reliable websites of national and international organizations, including official bodies, non-official institutions of renowned credibility aimed at addressing water reuse programs, national and international experiences on the reuse of urban drinking water, collection of concepts, laws and existing research projects in this area.

Moreover, the evaluation and validation study to the reuse of water were made on the premises of a fire fighting training center aimed at training personnel to operate in various sectors at onshore and offshore oil units, and achieve the following objectives:

- Draw attention of professionals, SMS consultants (Safety, Environment and Health), and public and private managers to the need to integrate water reuse nationwide within the principles of precaution in order to preserve the human and environment;
- Study the process of simplified treatment of reused water for firefighting training centers that does not involve sophisticated and expensive maintenance.

3 Definitions, classifications and forms of water reuse

The Brazilian Association of Sanitary and Environmental Engineering (ABES, 1992) classified water reuse in two major categories: drinking and not drinking.

- potable water reuse: direct potable reuse, reclaimed wastewater through advanced treatment is directly reused in the drinking water system. Indirect reuse drinking is the process in which the after treatment wastewater is provided in the collection of surface or ground water for dilution, natural purification and subsequent capture, processing and finally used as drinking water;
- non-potable water reuse: this type of reuse has great and diverse potential. As it does not require high levels of treatment, it has become an economically viable process and, consequently, developing rapidly. Because of the diversity of use, it can be classified as:
  - non-potable reuse for agricultural purposes: the main objective of this practice is the irrigation of crops such as fruit trees, cereals, among others, non-food plants, pastures, fodder. It is also suitable for watering livestock;
  - non-potable reuse for industrial purposes: covering the various industrial uses such as cooling, process water, utilities, and so on;
  - non-potable reuse for recreational purposes: reserved for irrigation of ornamental plants, sports fields, parks and also for filling ornamental or recreational ponds etc.;
  - non-potable reuse for maintenance of flows: maintenance of runoff watercourses promotes the use of planned treated effluents, aiming at a proper dilution of any pollutant loads in them, including diffuse sources, in addition to providing minimum flows in droughts;

- non-potable reuse for domestic purposes, these cases are considered for watering the garden, and sanitary discharge in large buildings;
- non-potable reuse for aquaculture: is the production of fish and aquatic plants in order to obtain food and / or energy, utilizing nutrients present in wastewater;
- non-potable reuse for aquifer recharge underground: the recharge of aquifers with treated effluents, which can be made directly by injection under pressure, or indirectly using surface water discharges that have received the amount.

In Asano et al.'s point of view (2007), reclaimed water is defined as an effluent conveniently treated in a sewage treatment plant for a specific intended reuse. Additionally, reuse of water directly requires the existence of a pumping system, or other transportation facilities for water supply. Indirect reuse is accomplished through the discharge of effluent to bodies of water for dilution or absorption. This type of water recycling is generally used for a specific use, and in specific ways to a defined user. That is, the effluent is to be captured again, and redirected back to this system of use. In this context, water recycling is predominantly practiced in the industry.

Hespanhol (2002) highlights three potential applications of non-potable water reuse: urban, agricultural and industrial. Non-potable urban uses involve less risk and should be considered as the first option for reuse in urban areas. However, special care must be taken when there is direct contact with reused public water. The greatest potential of this process are those based on treated sewage: Irrigation of landscaped areas in public buildings, homes and industry; aquatic systems such as decorative fountains and fountains; water reserve fire fighting protection; sewage in public restrooms, commercial and industrial buildings; street cleaning, trains and public buses.

4 Water reuse in a fire fighting training center

Water reuse assessment was held at the Centro de Treinamento de Combate a Incêndios {Firefighting Training Center} (Sampling Planning SA), located in the municipality of Rio das Ostras (Rio de Janeiro / Brazil), occupying a 17,000 m^2 area. The Center was built to meet the needs of companies in the oil industry and similar segments, based on the requirements listed in the NBR 14276 (ABNT, 2006), Rule 24 (DPC, 2009) rules, and other legislation that recommend the need for the standardization of firefighting training activities given by brigades with basic, intermediate and advanced knowledge, skills, and the necessary attitudes to control and prevent possible accidents. Teams should be guided through training that includes, among others, the practice of using smothering, cooling and insulation methods, by means of water extinguishing agents.

This project, which meets NBR 14.277/05 (ABNT, 2005) provisions, is dimensioned to a 50 (fifty) students / day demand. The main fuel used in the field is LPG (Liquefied Petroleum Gas), and the design of the indoor pipes used for fuel distribution meets the NBR 14750 (ABNT, 2001) provisions. Regarding the LPG system, the tank farm should be proportionate, using a P 500 (500 kg capacity) container as a reservoir.

The reuse system consists essentially of the following:

- The water used in firefighting leaks along with rain water to the gutters;
- From the gutters, the water goes to a rail box, where coarse solids are retained;
- Next, the water goes through a sand filter, where the solids are retained in suspension.

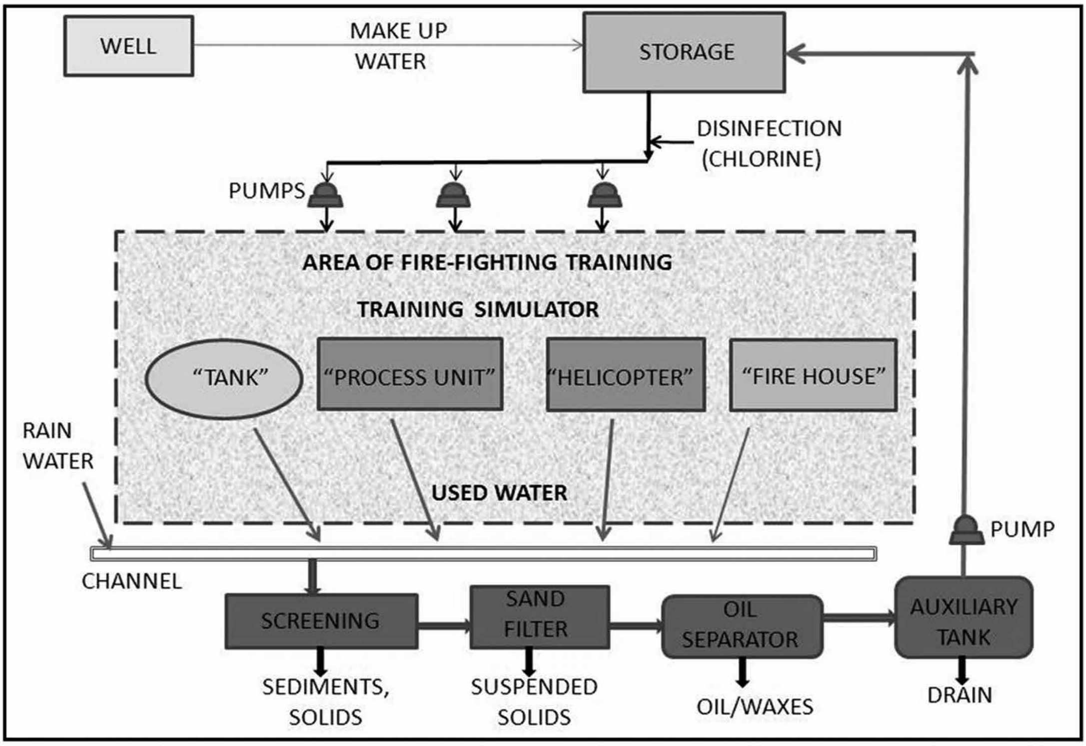

Figure 1 - Flowchart of the fire fighting installation
Source: Sampling Planning

The water flows continually into the OWS system (oil-water separator), where much of the oily sludge produced between the water- oil interaction is retained. In the OWS, effluents arriving in turbulent regime are sent, in the separator box, to the laminar flow, where with low drainage speed, and a longer than 30 minutes retention time, most of the oily products are separated from water. In order to retain the oily particles with a minimum of 10μm diameter, coalescent plates consisting of a bundle of PVC plates (Poly Vinyl Chloride), inclined at a 60° angle to obtain an effluent with a maximum concentration of 20 ppm OG (Oil and Greases) are used. The oily matter retained in the separator is concentrated within it by gravity, and the coalescence capacity of the plates on the liquid surface of the primary and secondary chambers. There, the oil accumulates and thickens until it is collected by the spillway, shaped as a gutter, located in the secondary chamber of the OWS, sending the already separated oily matter to the oil accumulation tank.

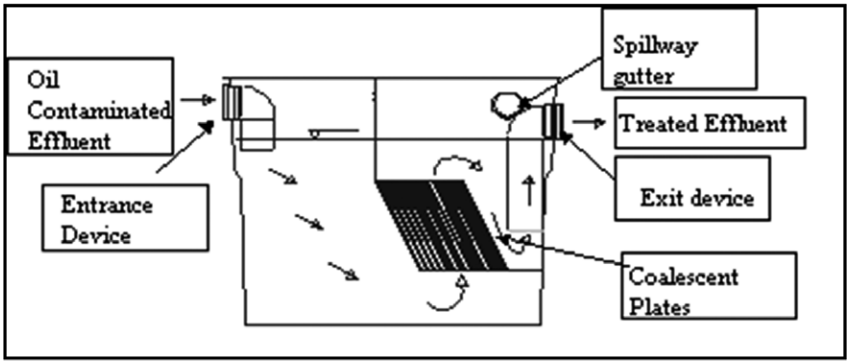

Figure 2 - Schematic of the OWS (water-oil separator).
Source: Sampling Planning

Water, with virtually no oil, flows into the buffer tank (reuse), and then it is pumped to the water tower. The circulated water and the makeup water (from the artesian well) are chlorinated to achieve the recommended values for disinfection. The water reuse is circulated up to its saturation point, in other words, when the amount of microorganisms and odors discourage its use, being then discarded into the sewage treatment plant.

When the water is discarded or, for any reason, there is loss of volume in the tower, makeup water from the well enters automatically. The oily sludge retained in the OWS is removed by a truck accredited by the environmental agency.

The water used in the system is monitored by the laboratory, where physic-chemical (pH, turbidity, chloride, total iron, alkalinity, sodium, total solids, conductivity and residual chlorine) analyses and bacteriological analysis (total coliforms, Escher coli) are carried out so that the residual chlorine levels are consistent with the disinfection process, i.e., between 0,2 to 0,5 mg Cl_2/L.

The water used in this center and exercise program is from an artesian well that feeds the water tower, and the rain water that spill into the channels.

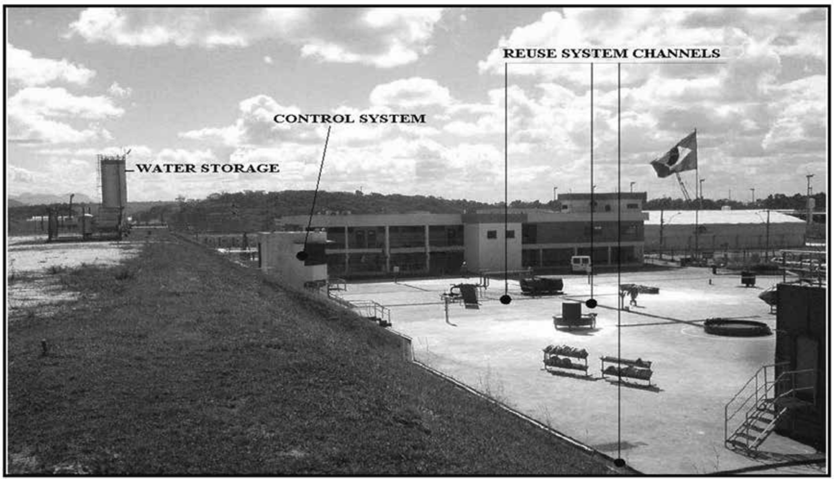

Figure 3 - Overview of the training center to highlight the castle and water channels for water collection
Source: Sampling Planning

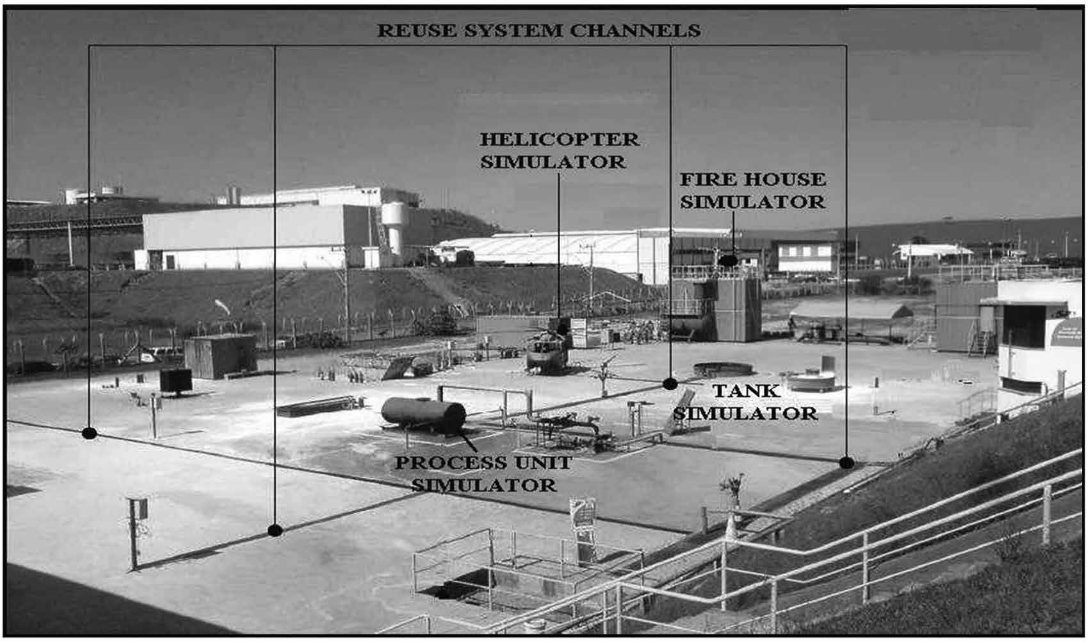

Figure 4 - Field aspect of firefighting training where there are practical exercises and identify the water separator and oil (OWS) and the channels as obstacles to the exercise of fire fighting, such as macaw, helicopter, process and system house machine

Source: Sampling Planning

It is estimated that the annual amount spent in other units, where there is no reuse system, is 200% to 300% higher. Moreover, the consumption of collected water tends to diminish by using LPG instead of diesel which adds a lot of oily sludge to the water, thus highly contaminating it.

Table 1: Water consumption in the training of firefighting and the trainees.

Year	Trainees (number)	Water consumption(m^3)
2006	1716	40
2007	7423	120
2008	6912	120
2009	5527	120

5 Conclusions

Based on studies conducted at the Fire Fighting Training Center, this study concludes that:

- Water reuse is an important strategy to be used in various urban and industrial segments. However, continuous monitoring of contamination by organic micro-pollutants toxic, pathogenic microorganisms and heavy metals is quite important in view of environmental pollution.

- Water scarcity, especially in large cities, leads to wise use of water reuse from sewage or industrial effluents.
- The reuse water system used at the Firefighting Training Center is a simple and creative technology option, because it reduces disposal of used water, and does not use water from natural springs protected by environmental laws.

References

ABES. Brazilian Association of Sanitary and Environmental Engineering: São Paulo [1992].

ABNT. Associação Brasileira de Normas Técnicas. *NBR14750*. Respiratory protective equipment: respirator compressed air line with a hood, for use in blasting operations. Rio de Janeiro, 2001.

ABNT. Associação Brasileira de Normas Técnicas. *NBR 14277*. Training facilities and equipment for firefighting. Rio de Janeiro, 2005.

ABNT. Associação Brasileira de Normas Técnicas. NBR14276. Fire Brigade. Rio de Janeiro, 2006.

ASANO, T.; FRANKLIN, L.; BURTON, F. L.; LEEVRENZ, H. L.; TSUCHIHASHI, R.; TCHOBANOGLOUS, G., *Water Reuse Issues, Technologies, and Applications*, New York: McGraw-Hill., 2007.

BARON, J. S.; POFF, N. L.; ANGERMER, P. L.; DAHM, C. N.; GLLEIK, P.H.; HAIRSTON, N. G.; JACKSON, R. B.; JOHNSSTON, C. A.; RICHTER, B. D.; STEINMAN, A.D. Meeting Ecological and Social Needs for Freshwater. *Ecology Applicated*, v.12, n.5, p. 1247-1260, 2006.

BRAGA, B. et al. Introduction to Environmental Engineering.– In: *The challenge of sustainable development*. New York: Pearson Prentice Hall, 2007.

DPC. DIRECTORATE OF PORTS AND COASTS, NAVY OF BRAZIL. Norma – 24, *Accreditation of Institutions for Teaching Courses for Professionals Non-Crew and Crew Non-Waterways*, Ordinance no. 129, September 30, 2009.

GOMEZ-LOPEZ, M.D., BAYO, J. G., CASCALES A., ANGOSTO, J..M. Decision support in disinfection technologies for treated wastewater reuse. *Journal of Cleaner Production*, v. 17, n. 16, p.1504-1511, 2009.

HARREMOES, P.; GEE, D.; MACCGARVIN, M.; STIRLING, A.; KEYS, J.; WYNNE, B.; VAZ, S. G. Late Lessons from Early Warnings: the Precautionary Principle, 1896-2000. *Environmental Issue Report*, European Environment Agency. Copenhagen, Denmark, n.22, , , 2001.

HESPANHOL, I. Potential for water reuse in Brazil: agriculture, industry, municipalities, aquifer recharge. *Journal of Water Resources*, v. 7, no: 4, p. 75-95, 2002.

LIU, F. Irrigation Strategies for Sustainable Environmental and Influence on Human Health.

Encyclopedia of Environmental Health, p. 297-303, 2011.

MACHADO, J. C. S. *The importance of reuse of fresh water for the national policy on water resources*, 2009. Disponível em: <http://www. jornaldaciencia.org.br >. Acesso em: 15 out. 2011.

MAINIER, F. B. Clean Technology: a law of society. In: BRAZILIAN CONGRESS OF ENGINEERING EDUCATION; COBENGE, 27., 12/15 September 1999, Natal, Rio Grande do Norte. Organized by the Federal University of Rio Grande do Norte and the Brazilian Association for Engineering Education. ABENGE, , 1999a. 7 p. *Proceedings* ... .

MAINIER, F. B. A critical routes for manufacturing industrial chemicals used in water treatment. In: CONGRESS OF AUTOMATION EQUIPMENT AND CHEMICAL INDUSTRY ASSOCIATION OF CHEMICAL INDUSTRIES (ABQUIM), 4,. 7 May 1999, São Paulo. 9p. *Proceedings*...

MEHNERT, D. U. Reuse of wastewater reuse in agriculture and environmental contamination by human enteric viruses. *Bio*, São Paulo, v. 65, n 1 / 2, p.19-21, Jan. / Dec. 2003.

MELIN,T., B.; JEFFERSON, D.; BIXIO, C.; THOEYE, W.; DEWILDE, J.; DEKONING, J.; WINTGENS, T. Membrane bioreactor technology for wastewater treatment and reuse, *Desalination*, v. 187, p. 271-282, 2006.

MIERZWA, J C.;HESPANOL, I. Program for managing water and wastewater industries to encourage rational use and reuse. *Sanitary and Environmental Engineering*, Rio de Janeiro, v.4, n. 1 / 2, p.11-15, Jan./Jun. 2002.

PLANET ORGANIC. 2008. Disponível em: <www.planetaorganico.com.br>. Acesso em: 15 dez. 2011.

REBOUÇAS, A.C.; BRAGA, B.; TUNDISI, J. G. (Org.). *Freshwater in Brazil - Capital ecological land use and conservation.* St. Paul: Scripture Press, 2006.

SHAW, S.; SCHWARTZ, R. Trading Precaution: The Precautionary Principle and the WTO (World Trade Organization). Yokohama, Japan: United Nations University Institute of Advanced Studies (UNU-IAS). International Organizations Center Pacific, 2005.

TUNDISI, J. G. *Water in the XXI century:* Facing the shortage. São Paulo: Editora Rima, 2005.

UN. United Nations. Environment. In: Stockholm Conference. Paulo Nogueira Neto. 2009. Disponível em: < http://www.mre.gov.br>. Acesso em: 18 nov. 2011.